

Accelerated Cycle-Life Testing On The Cyclon Lead-Acid Battery

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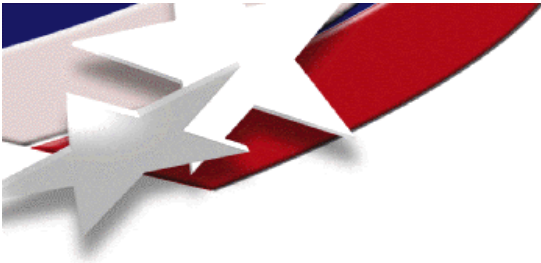
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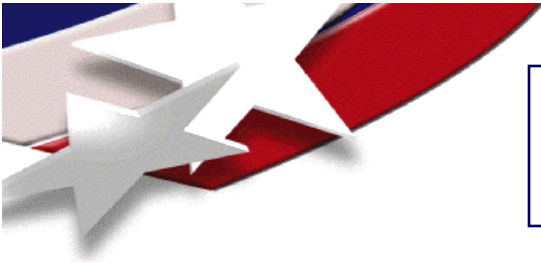
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Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



ACKNOWLEDGMENTS

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Introduction

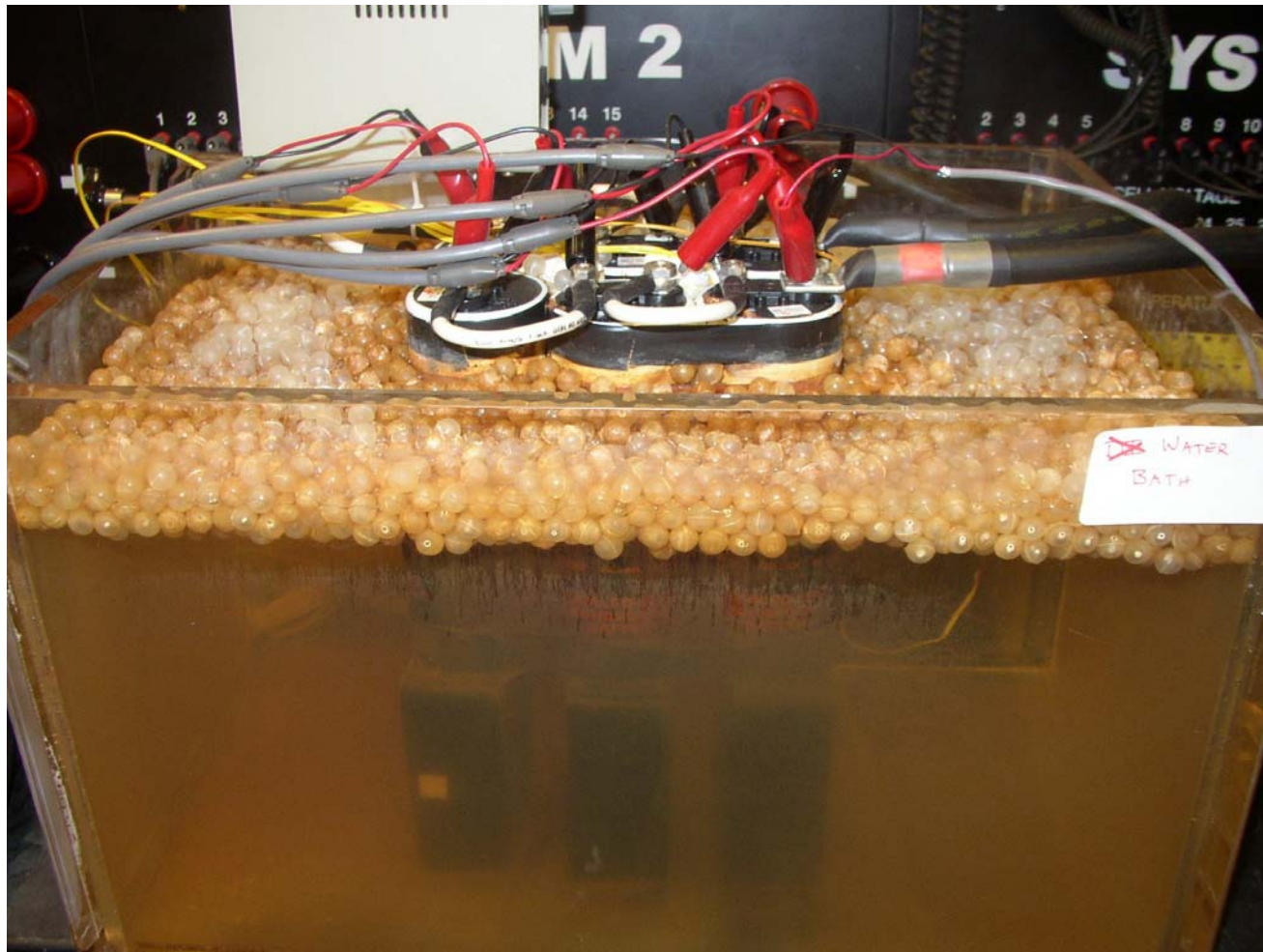
- ◆ The Cyclon valve regulated lead-acid (VRLA) battery (25 Ah Cell) invented by the Gates Corp. and manufactured by EnerSys is a cylindrically wound battery made from a high purity lead/tin grid alloy, which improves power, cycle-life, float-life, and increases the operational temperature range.
- ◆ Sandia's Power Sources Component Development Dept. tested this battery using a modified Battery Council International (BCI) and supercapacitor test procedure.
- ◆ Sandia was interested in this battery because:
 - ❖ the manufacturer's high cycle-life of 5,000 cycles at 10% DOD at 25°C,
 - ❖ high temperature performance, and
 - ❖ as a possible low cost replacement for supercapacitors.

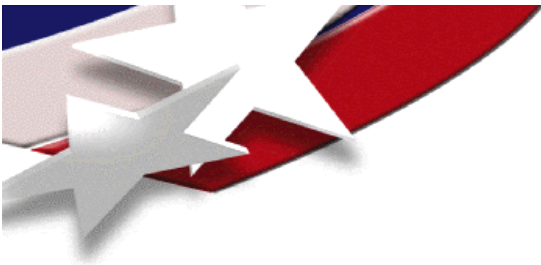


Modified BCI Test Procedure

- ❖ **Modified BCI test procedure, “Life Cycle Testing Of Lead-Acid Industrial Storage Batteries For Motive Power Service”**
 - Immerse in 46°C water bath
 - 0.2C (4.9A) discharge/charge rate
 - Fixed discharge/charge time at slightly over 30 minutes
 - Finish-charge every 100 cycles, 12 h at 2.47 vpc (14.85V)
 - Capacity test at 0.2C rate after each finish-charge
 - End-of-life at 80% initial capacity

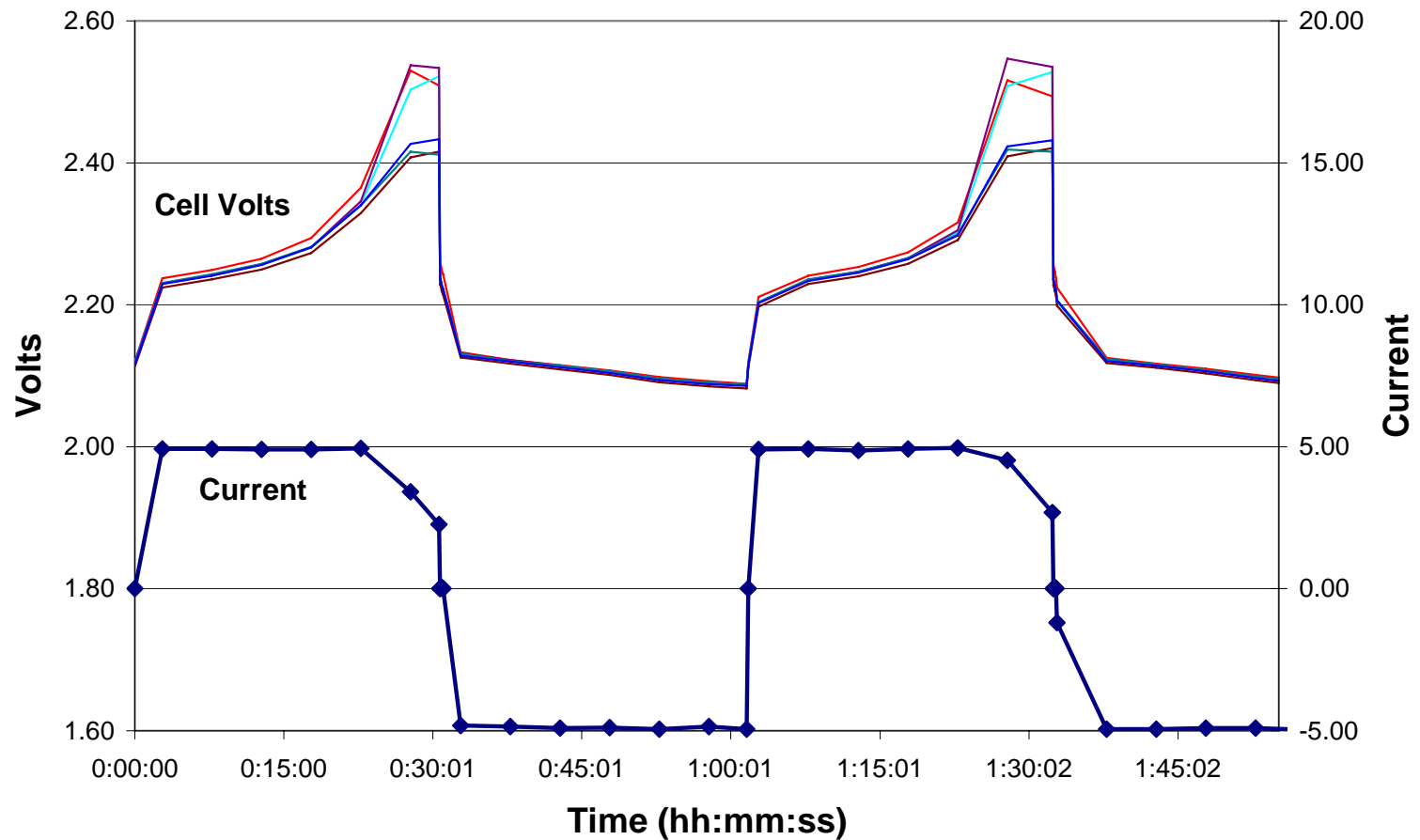
Cyclon VRLA Battery Under Test

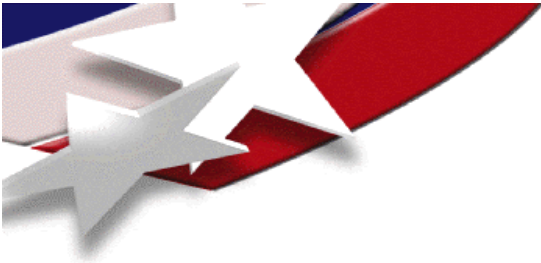




BCI Cycle-Life Test Cycle Profile

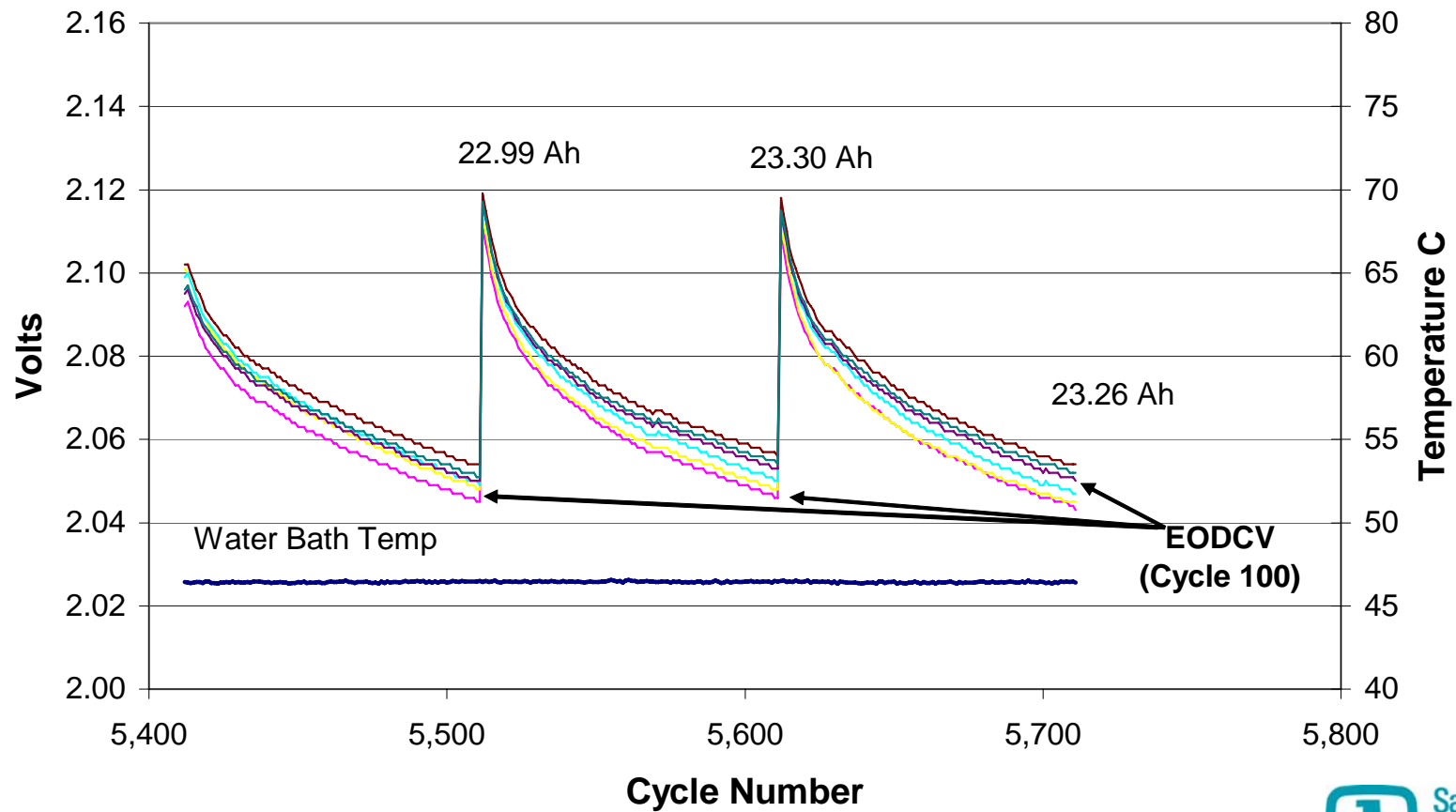
Cyclon Cycle-Life Test
Cycle #5

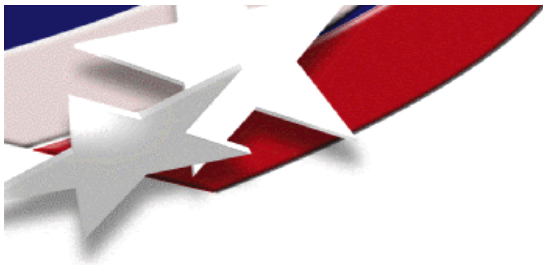




End-of-Discharge Cell Voltage

Cyclon Lead-Acid Battery Cycle-Life Test End-of-Discharge Cell Volts

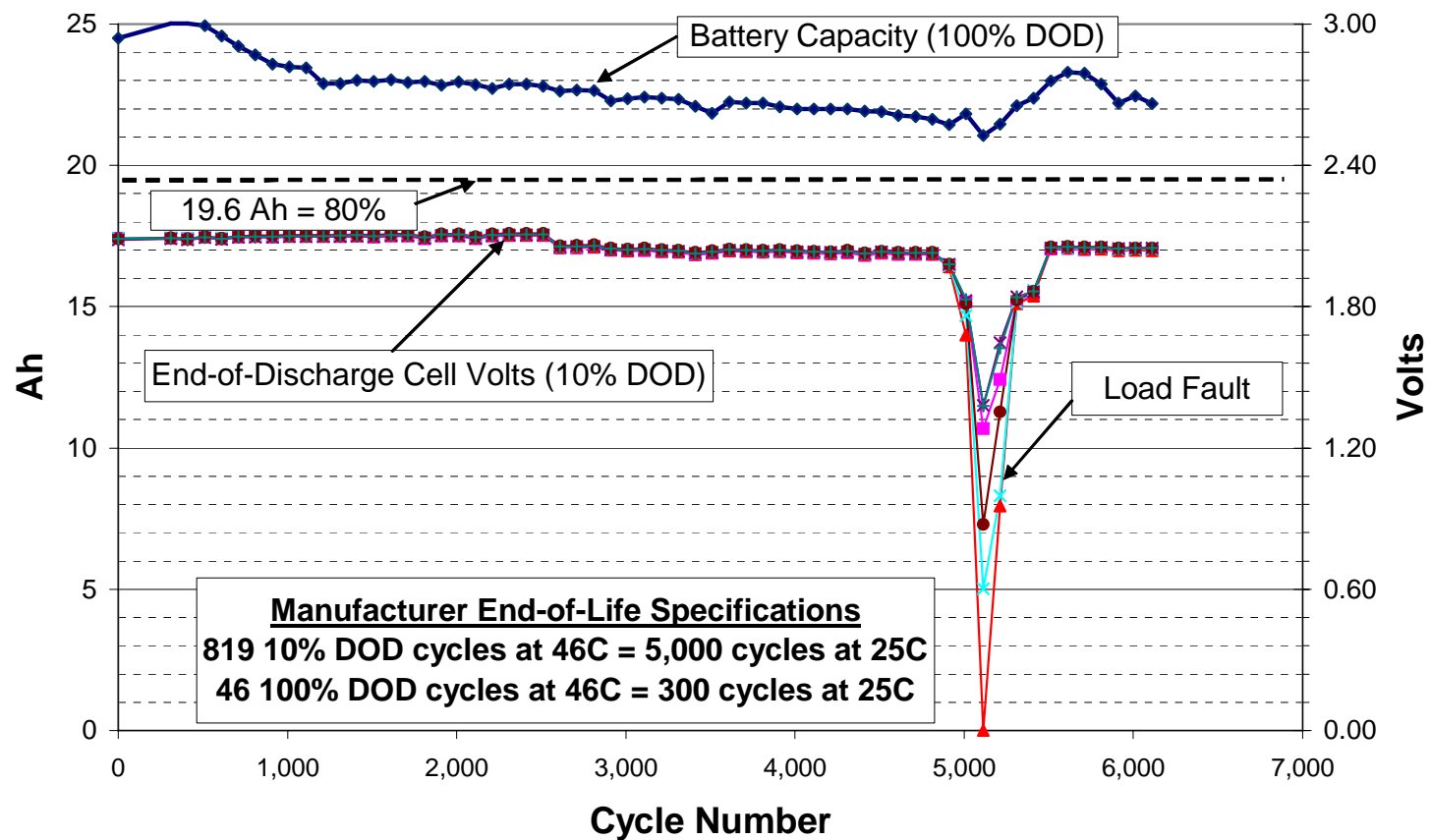


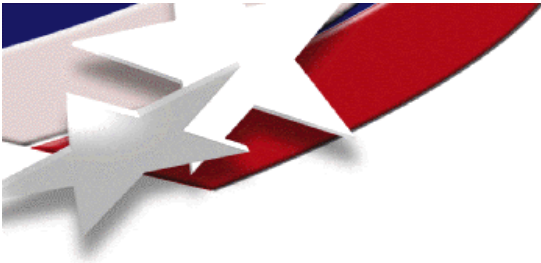


Cycle-Life Test Results

Cyclon Lead-Acid Battery BCI Cycle-Life Test

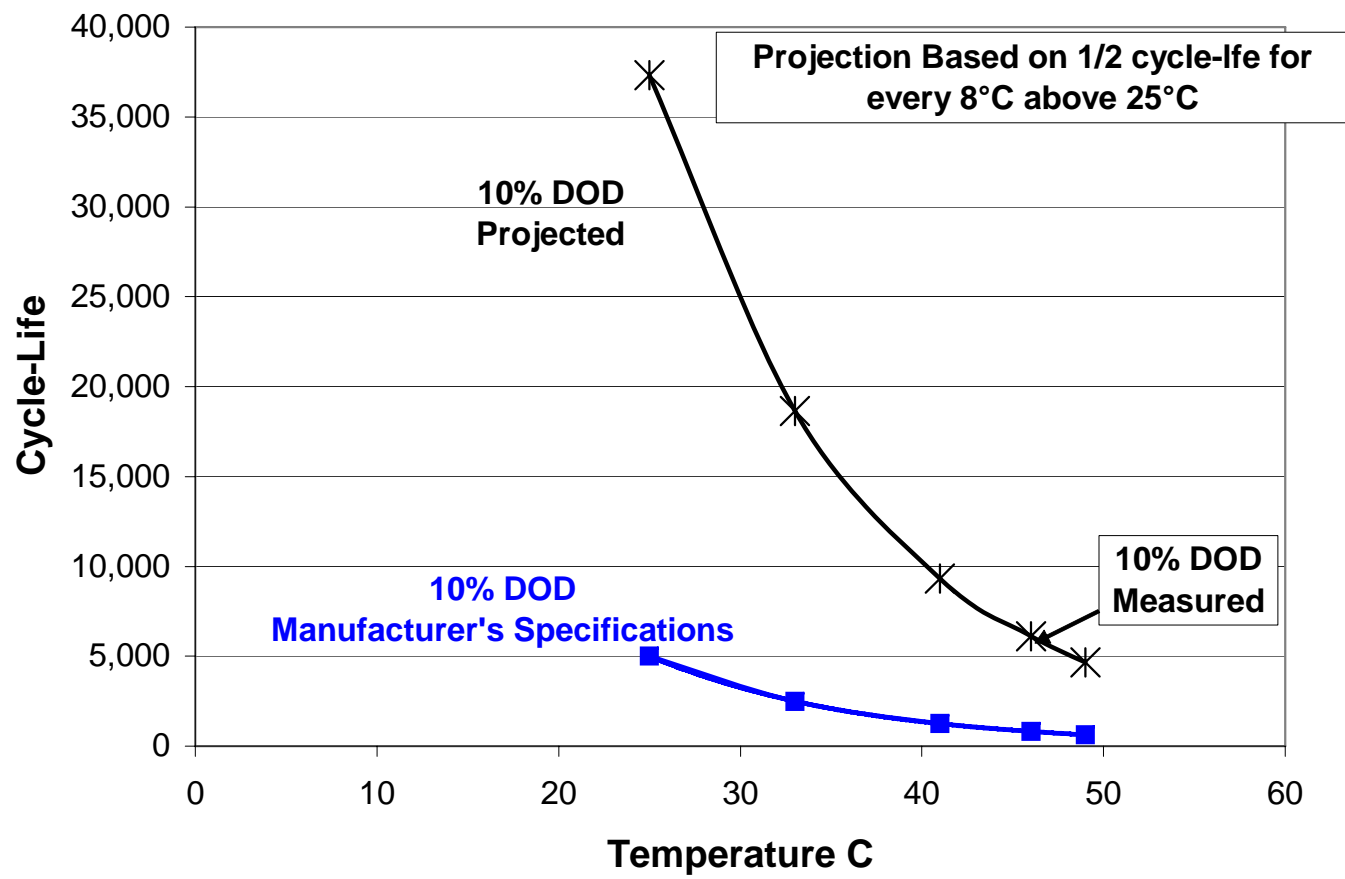
Test Temperature = 46C





Projected Cyclon Deficit-Charge Cycle-Life

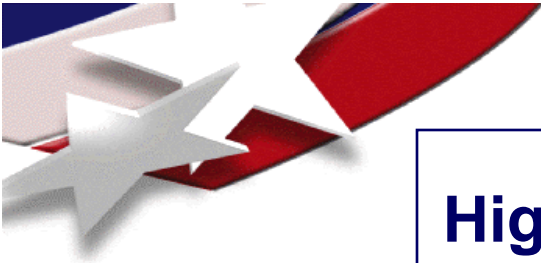
Cyclon VRLA Battery
BCI Cycle-Life Vs. Temperature





Cycle-Life Test Results

- The measured deficit-charge cycle-life has exceeded the manufacturer's specifications by about a factor of seven
 - Manufacturer's temperature adjusted cycle-life at 46C is 816 cycles
 - Measured 6,100 deficit-charge cycles and 58 deep-cycles at 46C
 - Capacity loss was less than 14% (24.51 Ah initial to a low of 21.06 Ah), but it also recovered to 23 Ah after 6,100 cycles.
 - A 5% increase in load current at cycle 5,000 caused a full discharge after 100 deficit-charge cycles. Battery recovered without damage.



High Power Supercapacitor Cycle-Life Test

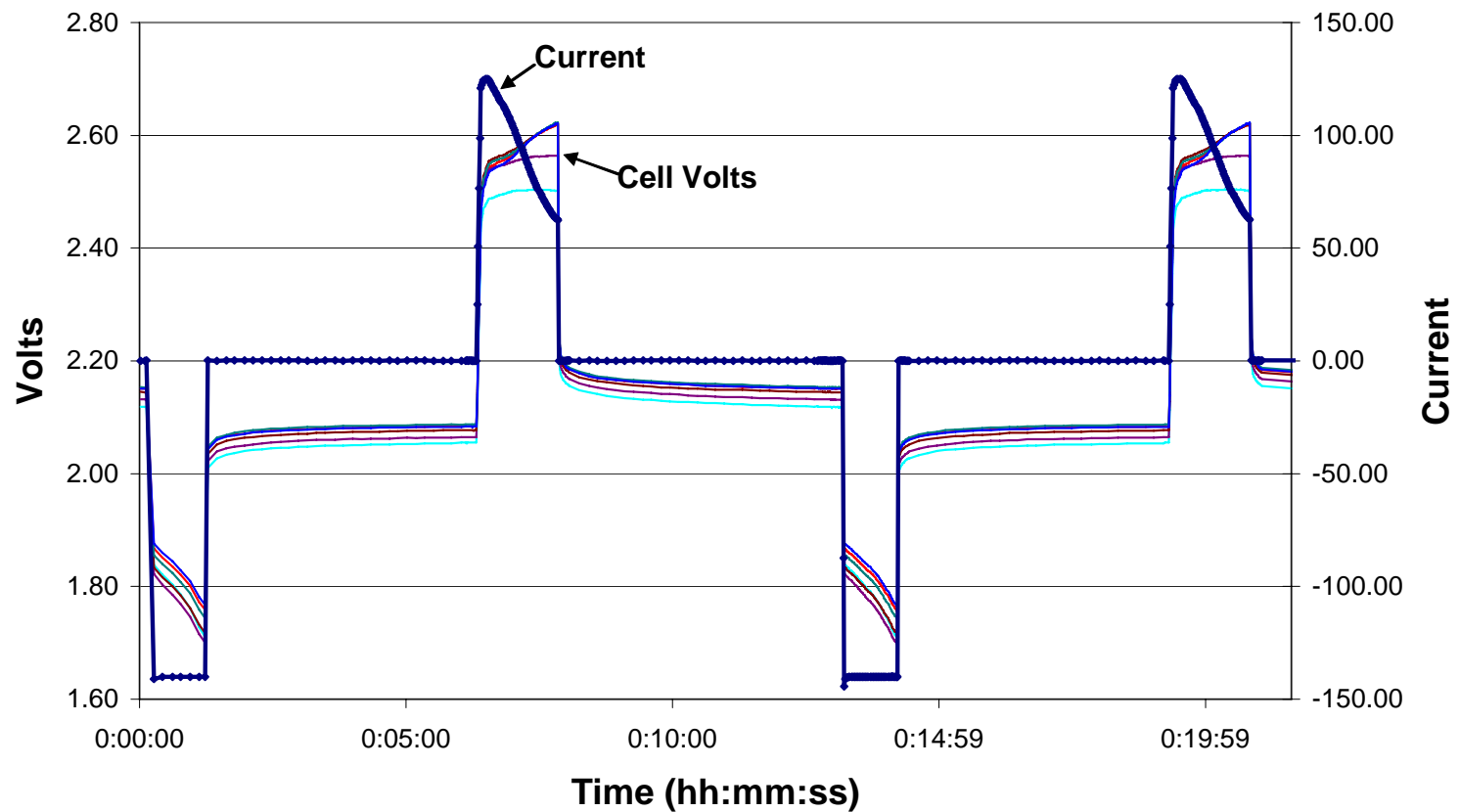
❖ Modified Sandia supercapacitor cycle-life test procedure

- Immerse in 22°C water bath
- 5.6C (140A) discharge for 65 sec. (2.5 Ah)
- 5 minute rest
- 5C (125A) charge for 94 sec. to 2.57 vpc (15.4V)
- 5 minute rest
- Finish-charge every 100 cycles, 12 h at 2.5 vpc (15.0V) at 22C
- Capacity test at 0.2C rate after each finish-charge



Cyclon High Power Cycle Profile

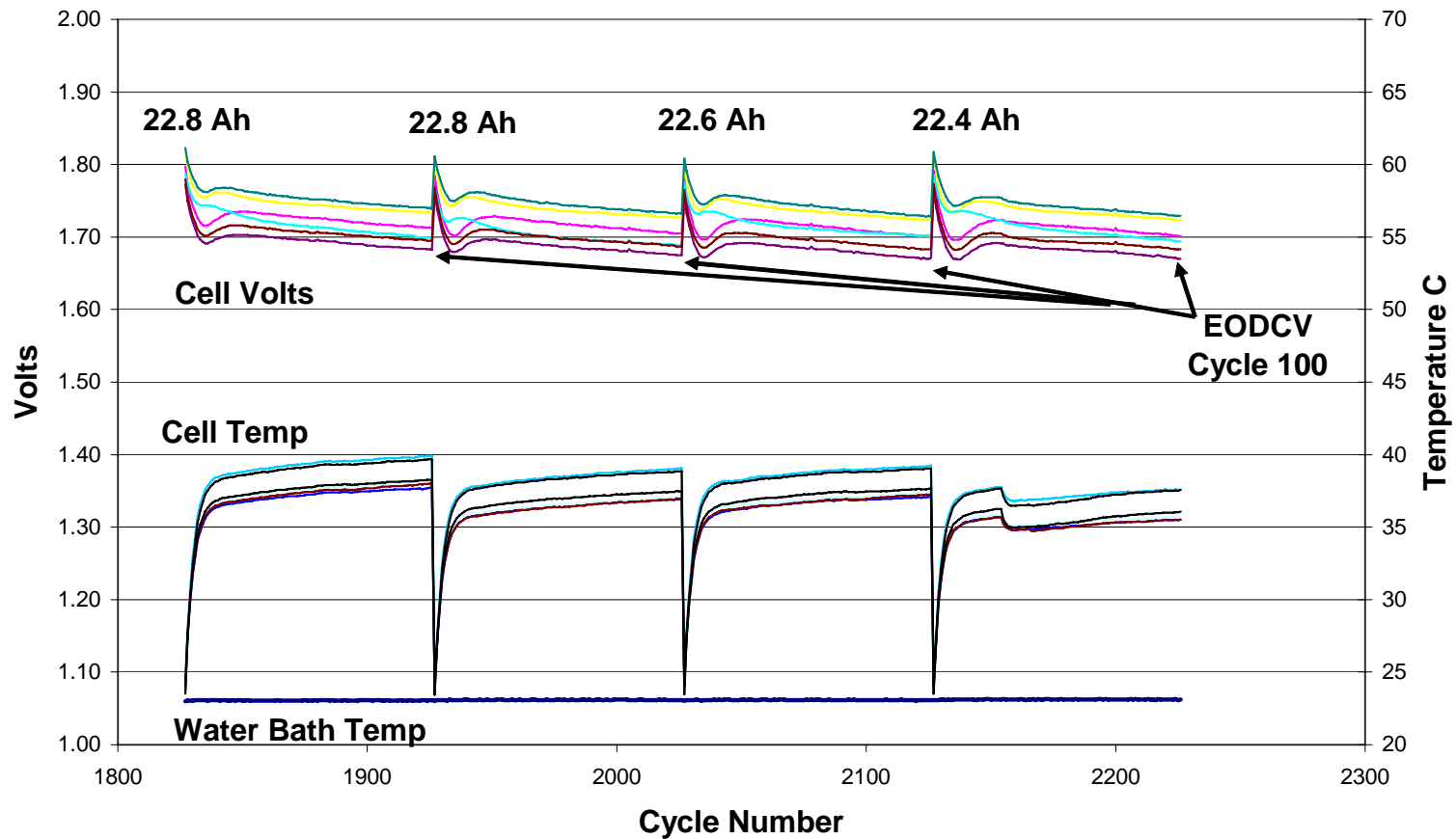
Cyclon High Power Test Cycle #38





End-of-Discharge Cell Voltage

Cyclon Lead-Acid Battery High Power Cycle-Life Test End-of-Discharge Cell Volts

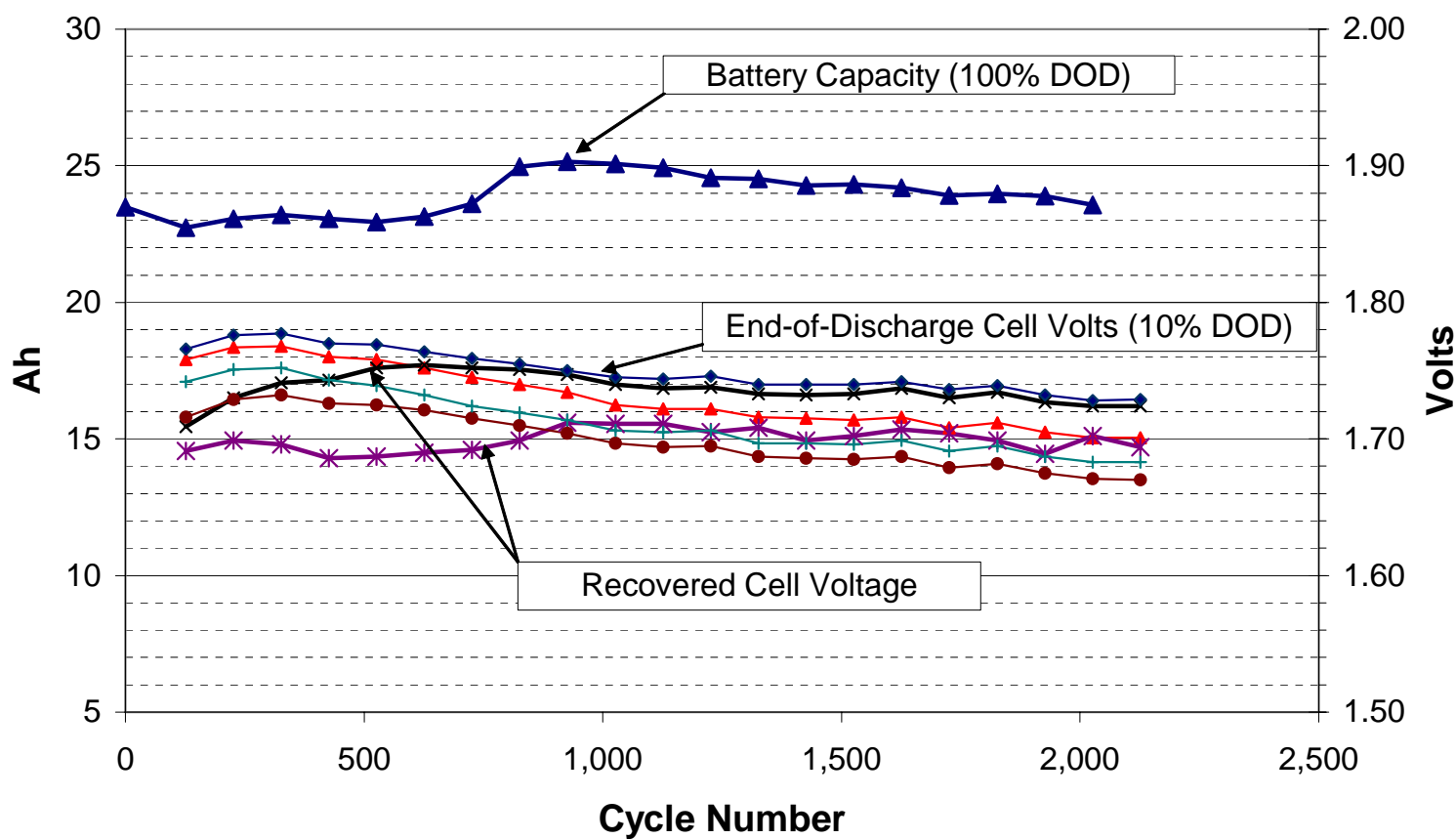




Cyclon High Power Cycle Results

Cyclon High Power Cycle Test

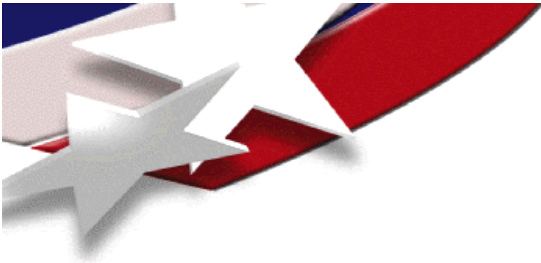
Exterior Cell Temperature = 38C





Cyclon High Power Cycle Test Results

- ◆ The Cyclon battery maintained relatively stable capacity after 2,100 cycles.
- ◆ Exterior cell temperature stabilized at about 16°C (38°C) above the 22°C water bath temperature.
- ◆ At about 800 cycles the capacity increased to 24.96 Ah from a low of 22.74 Ah. This increase in capacity is most likely due to the recovery in End-of-discharge Cell Voltage of two low voltage (low capacity) cells.



Summary

- ◆ The Cyclon battery exceeded the manufacturer's specifications for cycle-life by a factor of seven using deficit-charge cycling (**from 816 to over 6,100 cycles**) .
- ◆ Using the manufacturer's temperature vs. cycle-life relationship of, **$\frac{1}{2}$ cycle-life for every 8°C above 25°C**, the projected deficit-charge cycle-life at 25°C should be over 37,000 cycles.
- ◆ High power cycling at the 5.0C charge and 5.6C discharge rate indicated that the battery could handle high power applications if the required cooling and/or cycle profile was used.
- ◆ At about \$0.64 per Watt-hour the Cyclon VRLA battery could be very competitive in some high power applications where supercapacitors or oversized VRLA batteries would normally be used.